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SLEEP PATTERNS OF WORKERS ON ROTATING SHIFTS

J. Foret and O. Benoit

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16. Abstract

Workers who have been on rotating shifts for several years have served as subjects for the recording of the EEG during nocturnal and diurnal sleep. The duration of sleep is reduced when it must take place during the daytime, or, more generally, at times other than usual sleep periods.

The later the subject goes to sleep, the shorter is the duration of daytime sleep. The amount of daytime paradoxical sleep (PS) is less than during the night but the amount of slow wave sleep is practically the same in these two conditions. The amount of PS increases as a function of time in a period of sleep during the night as well as during the day, but it increases more rapidly during the first cycles of daytime sleep.

The amounts of PS and SWS are dependent on the time when sleep begins but in different manners: the occurrence of PS

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SLEEP PATTERNS OF WORKERS ON ROTATING SHIFTS

J. Foret* and O. Benoit*

In the past few years, the problem of the physiological effects /337** of changes in the sleep-wakefulness alternation has been extensively studied (Lille, 1967, Weitzman et al., 1970, Berger et al., 1971; Kripke et al., 1971; Knauth and Rutenfranz, 1972). These investigations took place under one of two extreme conditions. They involved either acute inversions in volunteer subjects or prolonged (one week or more) changes in shifts of workers. In fact, in the industrial realm, more and more imtermediate situations are found with rapidly alternating time tables (3 or 4 days). Moreover, holidays and weekends interrupt work periods and disrupt adaptations with a return to normal time tables. In this study, sleep of workers on alternating time tables was described according to sleep duration and pattern of sleep stages. Diurnal and nocturnal sleep periods were compared, and the influence of the time of day or night on the structure of sleep was emphasized.

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*Laboratory of Physiology of Labor, 41 Rue Gay Lussac, F-75005 Paris, and Laboratory of Physiology — CHU Pitié — Salpétrière, 91 Bld. de l'Hôpital, F-75634 Paris Cedex 13 (France).

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Methods

The sleep of 19 adult male subjects was recorded during periods of sleep at day and at night. Most of the recordings were taken in a sleep laboratory. Certain controls were performed at the place of work through the use of a magnetic recorder. All of the recordings were taken during work periods at times when the subjects would normally have slept if they had not been involved in this investigation.

Among the 74 recordings, 53 were usable. They were classified according to Table 1.

TABLE 1

Population	Number of recordings			
	Night	Day	Late night	Total
Train conductors N = 5	13	2	6	21
Night shift on the Metro N = 9 (22:30 - 6: 30)		9		9
Mail sorters N = 5 (21:30 - 5:30)	7	16		23
Total 19	20	27	6	23

Recordings were taken several (2 to 5) times for each subject, most often at night and during the day.

The sleep period were reclassified into: Day sleep, if it began after 6 a.m.; Night sleep, if it began after 1 a.m.; and Late night sleep, if it began between 1 and 6 a.m. /338

The ages of the subjects ranged from 27 to 49 years. The older subjects were train conductors (mean = 41.5 years). Past history of sleep under alternating time tables was variable, and was very long for some train conductors (up to 20 years). It was not less than two years for any subject.

Recordings and analyses of tracings were performed according to the terminology of Rechtschaffen and Kales (1968). In addition to EEG changes, eye movements (O.M.) were recorded by 3 electrodes, 2 on the external orbital region and one between the eyes. Amplitude, direction, or rapidity of eye movements were not taken into account.

The electromyogram of the chin was taken by two electrodes placed under the chin. In addition, cardiac and respiratory rhythms and possible environmental noises were recorded. The following abbreviations will be used: PS = paradoxical sleep; SWS = slow wave sleep (stages 3 and 4); NPS = non-paradoxical sleep, or total sleep minus PS.

Results

The results will be analyzed according to sleep duration and composition of sleep under the three types of time tables studied (night sleep, late night sleep, and day sleep).

1. Duration of Sleep

A. Total duration of sleep

Excluding sleep interrupted to resume work, the means taken from the recordings were as follows:

Night (min)	475 ± 68.8 min
Day (min)	356 ± 99.9 min
Late night (min)	346 ± 71.7 min

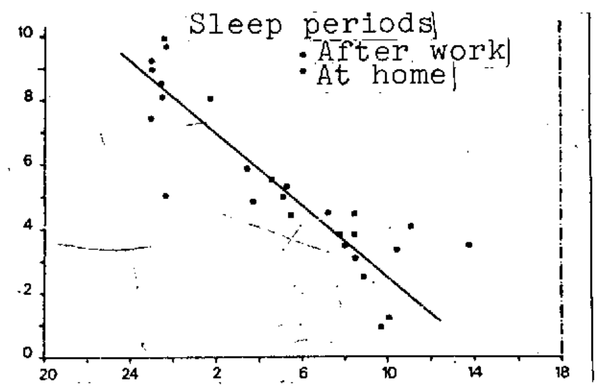
To total duration of diurnal sleep, like that of sleep beginning after 1 a.m., is about two hours shorter than the total duration of night sleep. These differences are significant ($p < 0.01$).

The variability in the duration of diurnal sleep is particularly large. This could be due to the fact that the time at which day sleep begins is more variable than that for night sleep.

B. Total duration of sleep as a function of time of day

The duration of sleep periods was studied as a function of the starting time for one of the occupational categories, train conductors (Figure 1) (Foret and Lantin, 1972). The duration of unlimited sleep at home, like that of sleep after the end of work, was related to the starting time of sleep by a linear plot with negative slope (correlation $Y = 0.94$, $p < 0.001$).

The later a sleeper goes to bed, the less he sleeps. Awakening nearly always takes place at the same time (between noon and 2 p.m.), whatever the time of going to bed.



Time of onset of sleep

Figure 1. Duration of sleep, expressed in hours, as a function of the time of sleep onset. The equation of the regression line is: $Y = 0.87x + 335$, where, expressed in minutes, Y represents the duration of sleep and X the time lost per minute

C. Total duration of sleep as a function of the duration of preceding wakefulness

A possible relationship between the duration of sleep and that of preceding wakefulness was investigated. In 38 instances for which these variables were known, the correlation between duration of sleep (Y) and duration of preceding wakefulness (x) was calculated without regard to the time table of sleep. We found $r = 0.51$, which is significant at the 0.001 level. The equation for the regression line was:

$$y^{hour} = -0.26x^{hour} + 10.9$$

(Figure 2).

The duration of sleep is thus <u>inversely proportional</u> to the duration of preceding wakefulness.

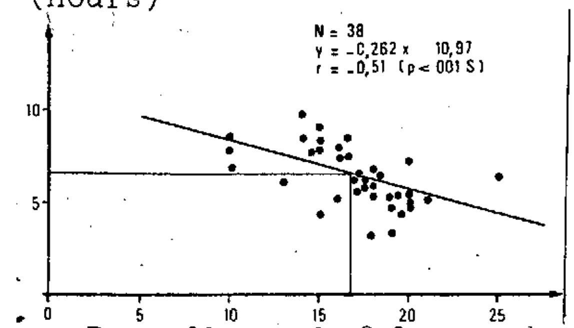


Figure 2. Duration of sleep as a function of the duration of preceding wakefulness. The vast majority of recordings used were taken after periods of wakefulness of durations between 14 and 22 hours. The regression line is thus significant only for the portion corresponding to moderately long periods of wakefulness (from 14 to 24 hours). Thus we can predict a period of sleep of 6.6 hours for a duration of wakefulness of 16.8 hours ($\bar{y}$ = 6.6 hrs, $\bar{x}$ = 16.8 hrs)

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2. Organization of Sleep

A. Absolute durations of different stages

The mean durations (in minutes) of different stages of sleep (night sleep and day sleep are given in Figure 3.

Because absolute duration is being plotted, the curve for diurnal sleep, which is shorter than night sleep, lies entirely below that of night sleep. The shortening of the different stages is not proportional to the overall reduction, but takes place in stages 1 and 2 and PS, while the amount of diurnal and nocturnal SWS is not significantly different.

Although diurnal PS is less than nocturnal PS, the two did not differ significantly. On the other hand, stages 1 and 2 are shortened to a highly significant extent ($p < 0.001$) (by an average of 45 minutes).

To delineate more closely the observed changes, the percentages of each stage were studied first as a function of the duration of sleep, then as a function of the order of cycles, and finally, as a function of the starting time of sleep.

B. Percentage of the stages as a function of the duration of sleep

Sleep duration is a very important factor in the composition of sleep. As in a normal night (Verdonne, 1968; Webb, 1971, SWS overwhelmingly dominates at first, then diminishes gradually, while PS has an opposite course of change. The different types of sleep

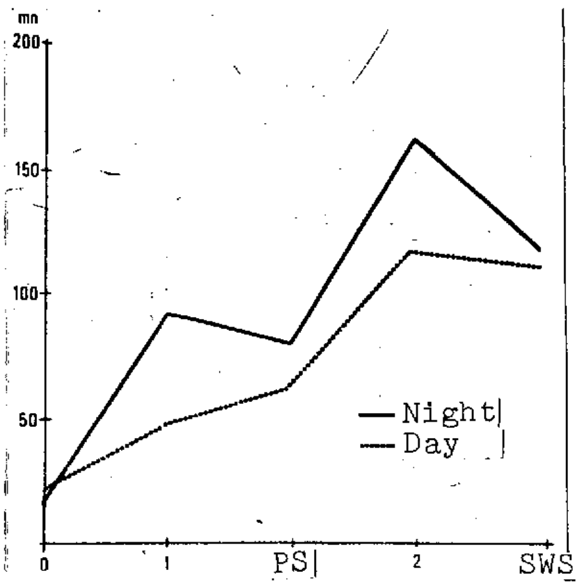

Figure 3. Absolute mean amounts expressed in minutes, of different stages for nocturnal sleep (N = 20) and for diurnal sleep (N - 27)

(night, day, and late night) were thus compared with equal durations to calculate the percentages of SWS and PS (Figure 4).

In every case, the percentage of PS increases with sleep duration. The difference in percentage of PS observed between day and night for sleeps of 4 hours is barely significant ($p < 0.05$).

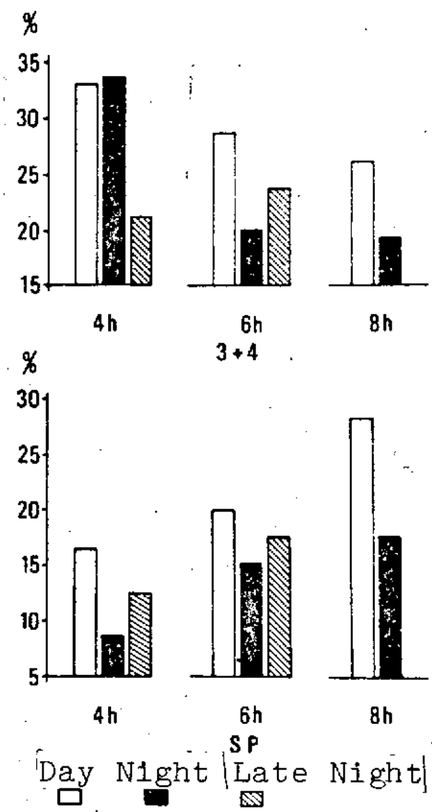

Figure 4. Changes in the percentage of paradoxical sleep (PS) and slow wave sleep (SWS) for sleep of 4, 6, and 8 hours duration for the three categories: day sleep, N = 17; night sleep, N = 18; late night sleep, N = 14. This figure shows how the percentages of SWS and PS change when the duration of spontaneous sleep lengthens

The percentage of SWS diminishes with the duration of sleep, at night or during the day. As for late night sleep, this percentage ($p < 0.05$) is significantly less for durations of 4 hours, and increases slightly at the limit of significance ($p < 0.10$) for sleep of 6 hours.

These changes are comparable to those in the representation of stages of sleep during successive hours of the same night (Webb, 1971). The abbreviated sleep periods thus appear similar to those of the beginning of night. They follow the laws of internal organization of sleep which persist regardless of the time of day or the sleep which is produced. Nevertheless, with sleep periods of equal duration, some effects of the time table can be seen.

C. Distribution of SWS and PS as a function of the order of cycles

The mean durations of PS and SWS were calculated for all of the /340 first cycles, then for the second cycles, and so on, without taking into account the exact time of occurrence of PS and SWS (Figure 5). (According to convention, the first cycle does not contain PS, since an entire cycle is defined as between the beginning of a period of PS and the beginning of the next.) Under these conditions, it can be stated that PS and SWS have the same distribution during the day as at night, even though the curves at night remain on the same side of the day curves for the first 3 cycles. The curves for PS do not differ significantly. As for those of SWS, the observed difference from the fourth cycle is highly significant, while that of the second cycle is significant only at the level of $p = 0.10$.

D. Distribution of SWS and PS as a function of the starting time of sleep

Sleep periods of duration between 4 hours, 30 minutes, and 5 hours, 30 minutes were compared. The changes in the amounts of PS and SWS observed for sleeps beginning at 9 p.m., 11, p.m., 3, 5, and 8 a.m., are shown in Figure 6. Because of the small number

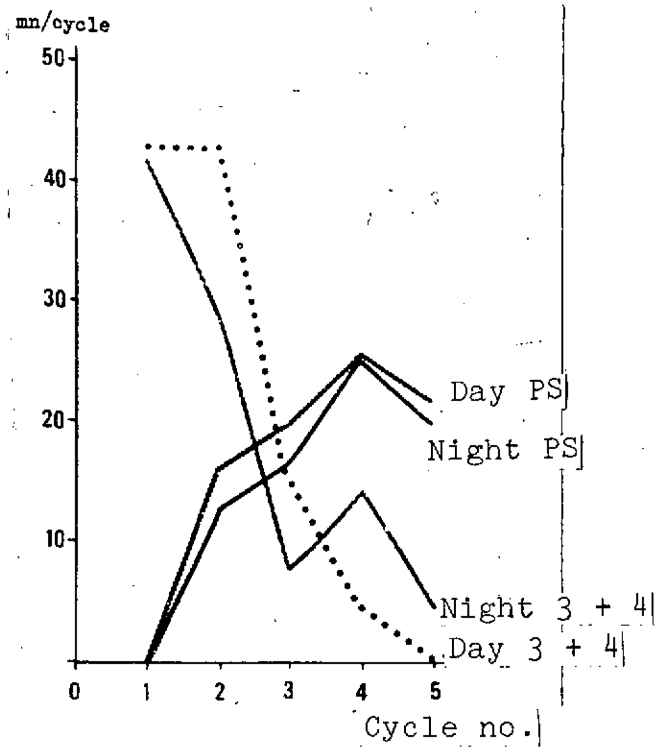

Figure 5. Mean amount of slow wave sleep (SWS) and paradoxical sleep (PS) as a function of the order of the cycle for night and day sleep, independent of the time of occurrence of periods of PS

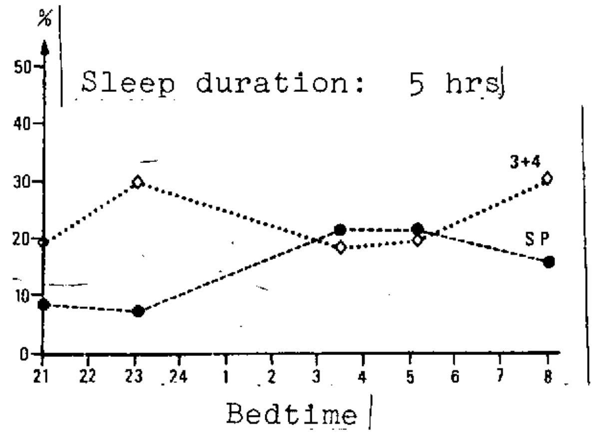

Figure 6. Percentage of different stages of deepness for sleep lasting approximately five hours and beginning at 9 p.m., 11 p.m., 3, 5, and 8 a.m.

of observations, this figure is only suggestive.

The amount of PS increases /341 in proportion as subjects go to bed at night, and attains its maximum for sleep periods beginning about 5 a.m. It then declines for those going to bed later.

The curve expressing the amount of SWS as a function of the time of going to bed appeared inverted with respect to the preceding one. The first peak corresponds to classical sleep of night sleepers. After a reduction during sleep from about 2 to 3 a.m., the amount of SWS again increases from 4 to 5 a.m.

Discussion

At time other than the usual hours of night, the composition of sleep is determined by the compromise which must be made among the requirements of the internal organization of sleep, the subordination of PS to the influence of the time of day or night, and other possible characteristics of the situation, including sleep deficit and preceding prolonged wakefulness, which primarily act on non-paradoxical sleep.

This compromise is due, in the first place, to the rigidity of the internal organization of sleep in the normal subject. Under imposed changes (displacements in the nycthemeron or reductions in duration), the structure of sleep remains undisturbed with respect to duration, alternation of cycles, and the differential distribution of SWS and PS. Taking into account this important point, our results nevertheless show, in subjects undergoing changing time tables for a number of years, an influence of the time of sleep on its duration and composition.

Contrariwise, with acute inversions, no differences have been found in the duration of spontaneous sleep and only minimal differences in the composition of stages of diurnal or nocturnal sleep (Weitzmann et al., 1970. After an inversion of time tables, however, a reduction in the amount of PS has been noted (Weitzmann et al., 1970). This disparity is probably due to the fact that the reported experiments were performed in the laboratory with time tables and durations of sleep imposed on young subjects. The reduction in diurnal sleep with respect to nocturnal sleep has, however, been reported (despite the differing methods of measurement) in recordings of sleep of night workers (Lille, 1967; Knauth and Rutenfranz, 1972; Bryden and Holdstock, 1973), as well as in studies of larger populations of workers on alternating time tables (Tune, 1969; Quaas, 1969).

Total duration of sleep

The total duration of sleep appears to be regulated by a circadian periodicity, as is suggested by the negative correlation between the duration of sleep and the actual time of onset. Likewise, the negative relationship between the duration of sleep and preceding wakefulness, already found by Aschoff (1970) in men deprived of temporal markers (isolation in a bunker), bears witness to the rigidity of physiological mechanisms which tend to restore the displaced sleep period to the usual time. According to our results, the effect of alimentary events appear to have a secondary influence. A meal which is habitually taken before diurnal sleep follows it at awakening in the afternoon.

It is clearly evident that the negative relationship between the duration of sleep and the duration of wakefulness is valid only for moderate durations of wakefulness. In fact, other factors should be in operation with very short periods of wakefulness (subjects having slept the day after night work and sleeping the night afterwards); for example, with a rest or with a change in alternation of time tables. Similarly, with very long periods of wakefulness comparable to sleep deprivation, the effects of fatigue and the need for recuperation can intervene and modify the relationship in the direction of lengthening the duration of sleep.

Organization of sleep

The differences in composition between day and night sleep approach those observed between the sleep of brief sleepers (less than 6 hours) and those of long sleepers (more than 9 hours) (Webb and Agnew, 1970; Hartmann et al., 1971). In these studies, as in our own, the total amount of SWS is remarkably stable (70 - 90 minutes). The difference in total duration originates in differences in stages 1 and 2, and secondarily in the differences in PS. These differences do not arise solely in changes of diurnal sleep duration with respect to nocturnal sleep. Other factors which are introduced by the inversion of time tables also exert an influence. /342

Certain findings argue in favor of a circadian periodicity for paradoxical sleep. The mean difference between the total amount of diurnal and nocturnal PS is smaller than that between brief and long sleepers (17 minutes as opposed to 60 minutes, with equal sleep durations). Paradoxical sleep is more common at the onset of diurnal sleep than in the onset of nocturnal sleep. With equal sleep durations, the amount of PS increases for sleeps beginning after 3 a.m., then diminishes for later sleep.

The changes in SWS can be explained by a circadian periodicity or by lengthening of the amount of wakefulness. According to the circadian hypothesis, the end of the night would be the portion of the nycthemeron least favorable to sleep, whereas the morning would constitute a period of renewed favorability for the appearance of SWS. On the other hand, however, the total amount of SWS does not seem to be highly dependent on the time table of sleep, and the bimodal aspect of the curve representing SWS as a function of the time of going to bed is not in agreement with a simple circadian variation. The circadian influence on the course of SWS, if it exists at all, remains secondary. The only argument in its favor is the reduction of SWS for sleep beginning between 3 and 5 a.m.

The primary factor thus appears to be the duration of preceding wakefulness (Webb and Agnew, 1971). In the instance of night work on an alternating time table, the duration of wakefulness is lengthened after several nights of work (because of the shortening of diurnal sleep), as well as during the first night of work. After a change in time table, there is most often a "white night", and thus a sleep deficit. If the increase in duration of wakefulness is to account for increases in the duration of SWS in sleep taking place after 5 a.m., it still does not allow an explanation of the observed reduction for sleep beginning about 3 a.m. This diminution could be due to a competition between PS and SWS. Sleep beginning after 3 a.m. contains the most PS. Given that considerable plasticity exists in the light states, this hypothesis is not very plausible. A better explanation would come from the secondary influence of a circadian periodicity which would compensate more or less for the increase in duration of wakefulness. The first hours of the morning constitute a pivotal period during which the sleep periods would be less clearly structured than with entirely diurnal or nocturnal sleep. The role of the sleep deficit appears negligible. The quality of SWS and of PS, day or night, are not significantly different, and do not show a "rebound" phenomenon, which would have been observed in cases of sleep deprivation (Webb, 1969). After some years of working on alternating time tables, sleep and, more particularly, PS are still influenced by the time table. Globus et al. (1972)

also reached this conclusion in a study of the cyclic organization of sleep in night workers. It seems plausible that the systems of wakefulness may also be influenced by this effect (Colquhoun, 1971; Mouret et al., 1972). The relative resistance of the circadian organization of wakefulness and sleep systems, whatever the cause might be, accounts for the double difficulty encountered by night workers — that of remaining alert at night and sleeping during the day. This difficulty is aggravated by the struggle between the "synchronizers" (light-dark alternation, social life, etc.) imposed by the shift in time table. In the case of shifts due to the crossing of time zones, this struggle against the external synchronizers does not interfere with the factors which apparently facilitate adaptation.

In conclusion, night remains the period when all of the factors which influence sleep combine in the most harmonious fashion. When other time tables are imposed, the resistance of circadian periodicity becomes manifest. Thus, the shortening of diurnal sleep probably reflects the inability of the organism to accommodate the conflicting factors discussed above.

Summary

Workers who have been on rotating shifts for several years have served as subjects for the recording of the EEG during nocturnal and diurnal sleep. The duration of sleep is reduced when it must take /343
place during the daytime or, more generally, at times other than usual sleep periods.

The later the subject goes to sleep, the shorter is the duration of daytime sleep. The amount of daytime paradoxical sleep (PS) is less than during the night, but the amount of slow wave sleep (SWS) is practically the same in these two conditions. The amount of PS increases as a function of time in a period of sleep during the night, as well as during the day, but it increases more rapidly during the first cycles of daytime sleep.

The amounts of PS and SWS are dependent on the time when sleep begins, but in different manners: the occurrence of PS seems to follow a circadian rhythm, with the most favorable period in the nycthemeron at the end of the night and at the beginning of the morning. On the contrary, SWS is much more dependent on the duration of the previous wakeful period.

The difficulties experienced by workers with alternating work schedules should be attributed more to the schedule shift than to the lack of sleep itself.

REFERENCES

Aschoff, J. Circadian Periodicity as the Basis of the Sleeping-Awake Rhythm. In the book: Ermuedung, Schlaf und Traum (Fatigue, Sleep and Dreams). W. Baust (Ed.). Stuttgart, Wissentshaftliche Verlag, 1970, pp. 59-98.

Berger, R. J., J. M. Walker, T. D. Scott, L. J. Magnuson and S. L. Pollack. Diurnal and Nocturnal Sleep Stage Patterns Following Sleep Deprivation. Psychonom. Sci., Vol. 23, 1971, pp. 273-275.

Bryden, G and T. L. Holdstock. Effects of Night Duty on Sleep Patterns of Nurses. Psychophysiology, Vol. 10, 1973, pp. 36-42.

Colquhoun, W. P. Circadian Variation in Mental Efficiency. In the book: Biological Rhythms and Human Performance. W. P. Colquhoun (Ed.). London, Academic Press, 1971, pp. 39-108.

Foret, J. and G. Lantin. The Sleep of Train Drivers: An Example of the Effects of Irregular Work Schedules on Sleep. In the book: Aspects of Human Efficiency, Diurnal Rhythm and Loss of Sleep. W. P. Colquhoun (Ed.). London, English Universities Press, 1972, pp. 273-282.

Globus, G. C., E. C. Phoebus and R. Boyd. Temporal Organization of Night Worker's Sleep. Aerospace Med., Vol. 43, 1972, pp. 266-268.

Hartmann, E., F. Baekeland, G. Zwilling and P. Hoy. Sleep Need: How Much Sleep and What Kind? Amer. J. Psychiat., Vol. 127, 1971, pp. 1001-1008.

Knauth, P. and J. Rutenfranz. Investigations of the problem of the sleep behavior for experimental shift work. Int. Arch. Arbeitsmed. Vol. 30, 1972, pp. 1 - 22.

Kripke, D. F., B. Cook and O. F. Lewis. Sleep of Night Workers: EEG Recordings. Psychophysiology, Vol. 7, 1971, pp. 377-384.

Lille, F. Sleep During the Day of a Group of Night Workers. Travail Humain, Vol. 30, 1967, pp. 85-97

Mouret, J. D., B. Renaud, P. Quenin, D. Michel and B. Schott. Monamines and Regulation of Vigilance. I. Collection and Biochemical Interpretation of Polygraph Data. In: Les mediateurs chimiques (Chemical Mediators). P. Girard and R. Couteaux (Eds.). Paris, Masson et Cie, 1972, pp. 139-155.

Quaas, M. Problem of adaptation, performance and organization of shift workers in East Germany. In A. Swensson (Ed.), Night and Shiftwork. Institute of Occupational Health, Stockholm, 1969, pp. 112 - 123.

Rechtschaffen, A. and A. Kales (Eds.). A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects. Public Health Service, U. S. Government Printing Office, Washington, D. C, 1968, pp. 1-62. /344

Tune, G. S. Sleep and Wakefulness in a Group of Shift Workers. Brit. J. Industr. Med, Vol. 26, 1969, pp. 54-58.

Verdone, P. Sleep Satiation: Extended Sleep in Normal Subjects. Electroenceph. Clin. Neurophysiol., Vol. 24, 1968, pp. 417-423.

Webb, W. B. Partial and Differential Sleep Deprivation. In the book: Sleep: Physiology and Pathology. A. Kales (Ed.). Philadelphia, Lippincott and Co., 1969, pp. 221-231.

Webb, W. B. Sleep Behavior as a Biorhythm. In the book: Biological Rhythms and Human Performance. W. P. Colquhoun (Ed.). London, Academic Press, 1971, pp. 149-178.

Webb, W. B. and H. W. Agnew. Sleep Stages Characteristics of Long and Short Sleepers. Science, Vol. 168, 1970, pp. 146-147.

Webb, W. B. and H. W. Agnew. Variables Associated with Split-Period Sleep Regimes. Aerospace Med., Vol. 42, 1971, pp. 847-850.

Webb, W. B., H. Agnew and R. L. Williams. Effect on Sleep of a Sleep Period Time Deplacement. Aerospace Med, Vol. 42, 1971, pp. 152-155.

Weitzmann, E., D. Kripke, D. Goldmacher, P. McGregor and C. Nogeire. Acute Reversal of the Sleep and Waking Cycle in Man. Effect on Sleep Stage Patterns. Arch. Neurol. (Chic.), Vol. 22, 1970, pp. 483-489.

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